

AI-Driven Humanoid Robot in the Service Sector

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Abstract— A multilingual humanoid receptionist robot has been developed to assist patients and simplify routine administrative tasks in hospital environments. The system interacts with users in multiple languages by employing natural language processing and speech recognition techniques. A Raspberry Pi acts as the primary processing unit, while an Arduino microcontroller controls motor and servo operations for movement and gesture execution. To ensure clear and reliable speech input in noisy surroundings, active noise cancellation is applied during voice capture. The robot is equipped with obstacle detection sensors that enable safe and autonomous navigation. In addition, it provides basic medicine-related guidance and supports doctor–patient communication through API- based integration. This system demonstrates the practical application of artificial intelligence and robotics in healthcare automation, leading to improved efficiency, accessibility, and overall user experience.

Keywords— Artificial Intelligence (AI), Multilingual Robot, Raspberry Pi, Arduino, Speech Recognition, Healthcare Automation, Autonomous Navigation, Obstacle Detection.

I. INTRODUCTION

Artificial Intelligence (AI) and robotics have brought major changes to service automation across various sectors, with healthcare emerging as one of the most significant application areas. Hospitals function as complex and fast-paced environments that demand continuous coordination among patients, doctors, and administrative personnel. Despite advancements, healthcare institutions commonly face challenges such as extended waiting times, communication gaps with patients, and insufficient staff at reception areas. To overcome these issues, intelligent service robots capable of multilingual interaction and context-aware assistance have gained considerable attention in recent years.

A multilingual humanoid receptionist robot has been developed specifically for hospital environments to assist patients, handle queries, and support doctor–patient communication. The system is designed to improve patient experience while reducing the workload on human staff by

providing features such as real-time interaction, guided navigation, and automated response

generation. It employs natural language processing (NLP) and speech recognition techniques to understand and respond to users in multiple languages. To ensure accurate voice input in noisy hospital surroundings, active noise cancellation (ANC) technology is incorporated.

The system architecture integrates a Raspberry Pi as the central processing unit for AI computation and data processing, while an Arduino microcontroller is used to control motors and servos responsible for movement and gesture execution. The robot performs language identification, translation, and AI-based query processing through prompt engineering and an AI-driven API, enabling contextually appropriate responses. The generated output is then translated back and converted into speech to ensure smooth and user-friendly interaction.

The robot is capable of executing movement commands based on specific voice instructions, allowing navigation in

directions such as forward, backward, left, and right. Ultrasonic sensors are incorporated for obstacle detection and collision avoidance, ensuring safe and

autonomous movement in crowded hospital environments. During emergency situations, the system can send doctor alerts using ADB-based communication tools, creating a direct and reliable link between patients and medical professionals.

In addition, the system includes a short-term memory mechanism that temporarily retains interaction context during a session and is automatically cleared afterward to maintain user privacy and comply with ethical data handling standards. The internal knowledge base enables the robot to offer basic medicine-related guidance, perform context-aware decision-making, and adapt responses based on user behavior. Through polite and adaptive conversational patterns, the system delivers a human-like interaction experience that enhances patient comfort and trust.

The system demonstrates the role of service robotics in healthcare by improving efficiency, patient interaction, and automated assistance.

II. LITERATURE SURVEY

A review of existing literature reveals several dimensions of interaction between humans and robots within the service industry. The analysis indicates that humans and robots can work together effectively as a coordinated team. Based on this understanding, these interactions are commonly classified into different levels. The first level involves human-human relationships (HHR), while the second level focuses on human-robot relationships. This category further includes sub-levels such as Human-Robot Collaboration (HRC), Human-Robot Interaction (HRI), and combined Human-Robot Interaction and Collaboration (HRI-C). In addition, a third category known as Multi-Robot Systems (MRS) is identified, which includes Robot-Robot Interaction (RRI), Robot-Robot Collaboration (RRC), and integrated Robot-Robot Interaction and Collaboration (RRI-C). This classification framework provides a clear and comprehensive understanding of the various forms of interaction and collaboration between humans and robots in service-oriented environments.. [1].

Over the past decade, the development of humanoid robots has shifted from pure industrial automation to more socially integrated applications, including healthcare, education, and customer service. Various studies have emphasized the role of AI in enhancing these robots' autonomy and social capabilities, particularly in interactive contexts. Researchers have explored different models of interaction, including

reactive, adaptive, and proactive systems, enabling robots to respond appropriately to human behavior. Literature also shows the increasing integration of speech recognition, gesture interpretation, and affective computing, which helps humanoid robots function in dynamic human-centric environments. The growing body of research points to a clear trend: AI-driven humanoid robots are evolving from task-specific machines into versatile service agents capable of learning and adapting in real time. [2]

This paper presents the design of a novel humanoid robot head. This humanoid head is based on biological likeness to the human being, so that the humanoid robot could interact agreeably with people in various everyday tasks. An innovative contribution with regard to computer vision systems implemented in former humanoids lies in the proposed humanoid head's configuration, equipped with an omnidirectional stereo vision system. Furthermore, this design integrates human-like cervical vertebrae in order to support the head. They should subsequently serve as a physical interface to the pitch and roll movements of the humanoid robot's neck. Likewise, other sensors are added to improve the robot's performance during bipedal locomotion, i.e., inertial sensors. [3].

The Retail Service Robot (RSR) is an emerging robotic technology that employs Artificial Intelligence (AI) to provide automated in-store customer service has been significantly enhanced by the development of service robots. One of the most notable advancements in this area is the introduction of humanoid robots designed to resemble humans through facial features and human-like body structures. Studies indicate that robots with human-like appearance and social behavior tend to gain higher user trust and acceptance. Such systems contribute to increased productivity, lower labor costs, improved customer experience, and efficient inventory management through automation across sectors such as retail, hospitality, banking, healthcare, and education. [4].

Anthropomorphism helps explain how people interpret and relate to objects that display human-like traits. This concept is widely applied across various fields, including products, branding, advertising, and non-human entities such as robots. Early research by Mori (1970) examined human responses to robots that closely resembled humans in both appearance and behavior. Across these definitions, a common idea emerges—the attribution of human characteristics, emotions, or behaviors to non-human entities like

animals, objects, robots, or natural phenomena. Anthropomorphism-based AI robots are therefore described as intelligent systems designed with human-like physical features, emotional expressions, behavioral patterns, and relational qualities. By incorporating such human-like attributes, these robots are more easily accepted and effectively used by people. [5].

Humanoid service robots are physically embodied artificial intelligence systems that resemble human form and abilities. Their design is inspired by the human body, including its appearance, structure, and movement patterns. Powered by AI, these robots are capable of sensing their surroundings, engaging in two-way conversations, and performing movements that closely mimic human actions. Such robots can carry out tasks traditionally handled by human service staff while also enabling social interaction with users. Their human-like physical presence and conversational skills encourage users to perceive them as social entities, leading to emotional engagement rather than viewing them as simple machines. The integration of artificial intelligence and machine learning with robotics has therefore introduced a new phase of automation, marked by intelligent systems that can learn, adapt, and make complex decisions.

This literature review examines the fundamental concepts of artificial intelligence and machine learning in robotics, focusing on how these technologies enable robots to perceive their surroundings, reason effectively, and perform tasks with greater autonomy. It discusses various learning approaches used in robotics, including supervised, unsupervised, and reinforcement learning, and explains how these methods strengthen robotic learning capabilities. The review also emphasizes the role of AI and ML in allowing robots to adapt their behavior in dynamic and uncertain environments, thereby overcoming traditional limitations related to adaptability and real-time decision-making.

The use of artificial intelligence in the finance sector has progressed through several stages, shaped by technological developments and changing industry requirements. In the early phases, AI was adopted primarily to handle and analyze large amounts of data more efficiently. Initial AI applications were relatively basic, focusing on automating routine processes and improving operational performance. This evolution began in the 1980s with the introduction of expert systems, which relied on predefined rules to replicate human decision-making in areas such as credit

evaluation and loan approval [8]. These systems formed the foundation for more advanced AI solutions by illustrating the potential of computational algorithms in supporting decision processes. During the 1990s, further progress was made with the emergence of more sophisticated machine learning techniques, supported by increased computing power and the availability of larger datasets.

Tong, Liu, and Zhang (2024) offers a comprehensive review of humanoid robots, examining their current advancements and future prospects. It provides an overview of key technologies in ontology structure, control and decision-making, and perception and interaction. The authors identify emerging challenges, emphasizing the need for a deeper understanding of biological motion mechanisms, improved structural design, enhanced material applications, advanced drive and control methods, and efficient energy utilization. The integration of bionics, brain-inspired intelligence, mechanics, and control is highlighted as a promising direction for the development of advanced humanoid robotic systems. This paper serves as a valuable resource, offering insightful guidance to researchers in the field and contributing to the ongoing evolution and potential of humanoid robots across diverse domains.[9].

Duan et al. (2024) present a detailed review of human-robot object handover, which is a key element of human-robot collaboration. The authors analyze multiple factors that affect handover performance, including the robot's role as either a giver or receiver, the type of end-effector used such as parallel-jaw grippers or multi-finger hands, and the robot's capabilities in grasp planning and motion control. The study also describes the implementation of a human-robot object handover system using an anthropomorphic hand to validate the proposed handover process. Overall, the review provides valuable guidance for researchers and developers in designing effective human-robot handover methods and supports the integration of robots into human-centric environments [10].

Moriuchi and Murdy (2024) investigate the use of robots in

the service industry, with a focus on factors that influence human-robot interaction in dining environments. Through three experimental studies, they analyze the impact of anthropomorphism on customers' willingness to dine, the appropriateness of service robots across different restaurant types, and

the complexity of tasks assigned to robots. Their results show that although customers generally prefer services delivered by humans, they tend to be more accepting of robots in casual dining contexts. Furthermore, customers perceive robots as supportive tools that enhance the roles of human employees rather than replacing them. The study concludes that the success of service robots depends on matching their capabilities with the characteristics of the service setting and the specific tasks they are intended to perform.

The paper by Jleilaty et al. (2024) presents a distributed real-time control architecture for electrohydraulic humanoid robots, specifically the HYDROiD platform, aiming to emulate the functionality of the human nervous system. This architecture overcomes the limitations of centralized and decentralized systems by distributing intelligence across joint controllers, allowing each to make decisions, control actuators, and publish states independently. The system utilizes a master-slave topology with EtherCAT communication and employs real-time operating systems, such as Preempt-RT on the master controller and FreeRTOS on joint controllers, to ensure deterministic behavior and high bandwidth. Experimental validations demonstrated a 50% improvement in update rates and a 30% reduction in latency compared to other humanoid robots. This adaptable and modular architecture enhances the robot's responsiveness and safety, making it suitable for complex tasks and environments [12].

Chang et al. (2024) investigate how the perceived warmth and competence of humanoid robots influence customer tolerance of service failures in the hospitality sector. Through two experimental studies, the authors find that robots perceived as warm elicit less anger and higher tolerance for service failures, whereas those perceived as competent evoke more anger and lower tolerance. However, under exchange norms—where customers expect strict adherence to service agreements—tolerance is low regardless of the robot's perceived warmth or competence. These findings suggest that aligning robot design with relationship norms is crucial for managing customer expectations and mitigating negative reactions to service failures. The study offers practical guidance for hospitality managers on deploying humanoid robots effectively to enhance customer satisfaction. [13].

The paper by Yevsiev, Abu-Jassar, and Maksymova (2024) focuses on simulating forward and backward

movements of a humanoid robot using the Robot Operating System (ROS)

[14] and its visualization tool, RViz. The authors developed and tested programs to ensure the robot's stable and smooth movement along a predefined trajectory. To maintain balance and stability during movement, they implemented a "hand-washing" system within the ROS framework. Simulation results demonstrated the effectiveness of the fragmented program, with the robot accurately following markers placed along the virtual path. This study underscores the importance of ROS in modeling and testing collaborative robots.

Giallanza et al. (2024) explore occupational health and safety (OHS) challenges in human-robot collaboration (HRC), emphasizing the need for safer and more ergonomic automation systems that effectively integrate human cognitive abilities with robotic precision. The paper reviews current advancements in collaborative robotics, identifies persistent safety concerns, and highlights the importance of designing inherently safe systems through technical, procedural, and organizational innovations. It also underscores the need to incorporate human-centered design and cognitive engineering principles to foster worker trust, acceptance, and well-being—especially in sensitive sectors like healthcare. The study serves as both a state-of-the-art review and a call for future research to bridge gaps in safety, usability, and ethical considerations in HRC environments [15].

Barua (2024) examines the influential role of artificial intelligence and humanoid robotics in modern healthcare, highlighting their ability to transform diagnosis, treatment, and overall patient care. The chapter explains how AI improves diagnostic accuracy through large-scale data analysis, supporting early disease detection and personalized medical solutions. AI-powered humanoid robots are increasingly utilized to assist healthcare professionals in activities such as patient monitoring, rehabilitation support, and surgical procedures, thereby enhancing efficiency and reducing workload. The author also emphasizes the importance of ethical deployment, promoting human-centered approaches that focus on patient safety, trust, and well-being. Overall, the chapter identifies AI and robotics as key technologies reshaping healthcare delivery and improving outcomes within an evolving medical environment [16].

Merckaert et al. (2024) introduce a real-time, constraint-based planning and control framework for

robotic manipulators to ensure safe human-robot collaboration. Their approach integrates a Rapidly-exploring Random Tree (RRT) path planner with an Explicit Reference Governor (ERG) to address dynamic constraints such as actuator saturation, joint limits, and human presence in cluttered environments. This hybrid system enables the robot to adaptively adjust its trajectory, maintaining safety without sacrificing performance. Experimental validation on a Franka Emika Panda robot demonstrated that the combined RRT+ERG [17] method outperforms standalone RRT and ERG algorithms, effectively preventing constraint violations and avoiding local minima. The framework supports real-time human-robot coexistence.

During the COVID-19 pandemic, humanoid service robots quickly became valuable allies in supporting overwhelmed healthcare systems around the world. Designed with human-like shape, size, and movement, these robots seamlessly operated in spaces built for people, making them especially effective in hospitals. From assisting with patient monitoring to reducing direct human contact, they played a crucial role in both the early and ongoing stages of the pandemic. Real world examples from various hospitals highlight how these robots helped ease the burden on healthcare workers. Looking ahead, their continued development and thoughtful integration could help shape smarter policies, reduce public anxiety, and encourage [18] broader acceptance of robots in healthcare.

This paper explores the challenges of prototyping AI products, particularly for non-experts, due to AI's complex and unpredictable behavior and the lack of accessible tools. It introduces a conceptual framework developed using the Design Science Research (DSR) method, aimed at making AI prototyping more inclusive and effective. By leveraging no-code AutoML (NC AutoML), the framework allows individuals without coding or AI expertise to contribute meaningfully to the development process. The research shows that NC AutoML can simplify model training, reduce risks, and improve collaboration between AI experts and non-experts. It also demonstrates how this technology can enhance decision-making and drive innovation across various industries, making AI more accessible and impactful. Ultimately, the study highlights NC AutoML [19] as a valuable tool for developing human-centered AI products, helping bridge the gap between technical and non-technical stakeholders from the very beginning of the prototyping process.

This study examines the adoption of humanoid robots

within the tourism and hospitality sector, highlighting both their opportunities and associated challenges. Examples such as robots deployed in the Henn-na Hotel, Connie, and Spencer illustrate how automation can improve service delivery, efficiency, and accessibility, while also shaping cultural and social interactions. However, the implementation of such systems raises significant concerns related to ethics, data privacy, operational reliability, and potential workforce displacement. The research stresses the importance of a balanced, human-centered approach in which robots support and complement human staff rather than replace them, thereby maintaining the personal element central to hospitality services. It further emphasizes the need for strategic oversight, regulatory compliance, and ethical guidelines, including those outlined in the EU AI Act [20], to ensure responsible deployment. The study promotes a hybrid model that blends technological advancement with human empathy and calls for continued research into scalable, culturally adaptable solutions and their long-term effects on both employees and guests. Ultimately, an inclusive and holistic strategy is identified as essential for realizing the safe, ethical, and effective use of humanoid robots in hospitality environments.

This study explores how intelligent service humanoid robots are being integrated into the hospitality industry, using research from Cardiff Metropolitan University's EUREKA Robotics Lab as a foundation. Taking a phenomenological approach, the research emphasizes the importance of understanding human-robot interaction through direct, immersive experiences and case-based interviews. It identifies four key areas for successful robot implementation

[21] user interaction, AI-based service models, data protection, and clear responsibility for robot management. These elements are linked through continuous user feedback, which helps improve robot behavior and overall user experience. The study also emphasizes the importance of strong data security and clear legal frameworks for safe robot operation. Overall, the proposed model provides a practical roadmap for developing intelligent and interactive service robots in the hospitality sector.

This systematic review of 118 peer-reviewed studies examines how human-like service robots, often designed with gendered characteristics, influence consumer behavior in service environments. The review proposes a structured framework that explains how customers interact with such robots, highlighting

key aspects including interaction antecedents, consumer processing, outcomes, and moderating factors. The findings show that robot anthropomorphism, particularly gender representation, plays a significant role in shaping users' emotional, cognitive, and behavioral responses. Ethical issues such as data privacy and the potential impact of replacing human workers are also discussed. The review recommends that organizations adopt human-like robot designs thoughtfully by balancing technological capabilities with human strengths and maintaining transparent data practices. It further underscores the importance of hybrid service models that involve both robots and human employees. Although virtual influencers are not covered, the study offers valuable insights for management and marketing by identifying research gaps and suggesting future directions related to robot design, interaction methods, and consumer psychology in technology-enabled services [22].

Customer-facing technology is now increasingly prevalent in retail, and this research targets the application of social robots—embodied robots that engage with people—within a grocery store environment. From workshops, hands-on prototyping, and a customer survey with 39 participants during a field trial, the research establishes seven main roles social robots can play: store guide, sales promoter, shopping assistant, entertainer, store chef, product supervisor, and experience evaluator. Two robots were tested in real store environments and were found to interact effectively with customers while performing their assigned tasks. Survey results showed that although social robots are generally viewed positively, many customers still felt some discomfort with their presence in stores. While the findings highlight the potential of social robots in supermarkets, the study emphasizes the need for further research to better understand their impact and support smoother integration into retail settings [23].

Technology significantly enhances teaching and learning by enabling the creation of interactive environments that adapt to diverse learning styles. The use of humanoid robots such as Pepper combines advanced technology with human-like interaction, which is essential for effective education. Speech plays a crucial role in learning, yet students often face challenges due to accent variations or hearing difficulties. Displaying transcribed speech on the robot's screen helps improve comprehension in such cases. This study examines the integration of speech

transcription into the humanoid robot Pepper and evaluates its role as an educational assistant in both online and offline learning settings. The results show that Pepper's speech recognition system performs effectively across different learning environments, achieving strong scores on evaluation metrics such as ROUGE F-score, BLEU, Jaccard Similarity, and TF-IDF, along with a low Word Error Rate (WER) [24].

This study examines how consumers develop post-adoption behavior when using delivery robots, highlighting the rapid technological advancements in last- Technology Fit (TTF) model, the research proposes a framework that considers both direct factors and previously overlooked indirect factors, supported by data collected from 550 users. Structural equation modeling shows that hedonic factors such as anthropomorphism and gratification, along with utilitarian factors including user-facing technology performance, delivery task requirements, and service quality experience, significantly influence users' perceived TTF. Value-in-use and trust are identified as sequential mediators linking perceived TTF to word-of-mouth communication and the likelihood of service reuse. The findings support the need to incorporate both functional efficiency and user enjoyment in the design of delivery robots to enhance acceptance and overall experience. From a theoretical perspective, the study reinforces that perceived TTF is shaped by both hedonic and utilitarian elements, with gratification positively affecting TTF, in line with earlier research on user enjoyment in emerging technologies [25].

III. DESIGN AND IMPLEMENTATION

The design of *Monika*, an AI-powered multilingual receptionist robot, integrates hardware and software components to enable intelligent communication, context-aware responses, and autonomous control. The overall system architecture is structured around modular subsystems including speech input processing, AI-based decision-making, and actuator control, all orchestrated through a centralized Raspberry Pi processor.

System Architecture: The overall system is divided into three main layers -input processing, AI-based decision-making, and output control. The central processing unit of the system is a Raspberry Pi, which handles computationally intensive tasks such as speech recognition, natural language processing, and AI inference. The Arduino microcontroller functions as a motion and peripheral controller, managing servo

motors, ultrasonic sensors, and other actuators. Together, these units enable Monika to process user commands intelligently and perform both verbal and physical responses.

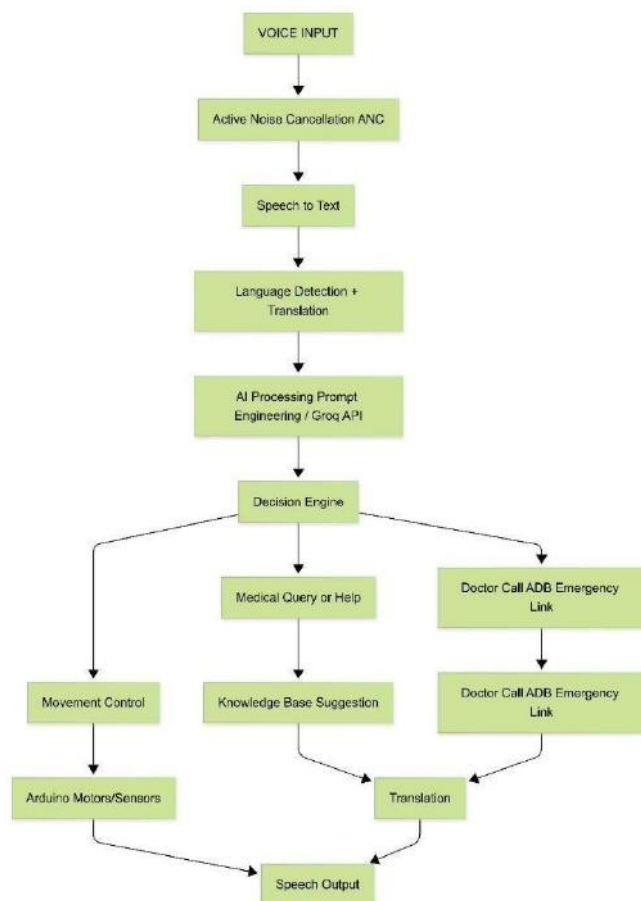


Fig.1. Methodology of the robot

Voice Input and Preprocessing:The system begins with the acquisition of voice input from the user through an embedded microphone. Since hospitals are often noisy environments, the input signal is processed using an Active Noise Cancellation (ANC) module to eliminate unwanted background sounds. This ensures clarity and enhances the accuracy of speech recognition. After noise filtration, the signal is converted from audio to text using a Speech-to-Text (STT) engine. The text output from this module serves as the basis for further linguistic and semantic processing.

Language Detection and Translation:To facilitate interaction with patients of different linguistic backgrounds, Monika incorporates a language detection and translation subsystem. This module identifies the spoken language automatically and translates it into a common processing language (typically English) using an AI-driven translation API. This capability makes the robot multilingual, enabling it to understand and

respond to users in multiple regional and global languages, significantly improving accessibility in diverse healthcare settings.

AI Processing and Decision Engine:The translated text is passed to the AI Processing Unit, where prompt engineering and the Groq API are utilized for contextual analysis and intelligent response generation. The system's AI model interprets the intent behind the user's input — whether it is a general inquiry, a medical-related question, or an emergency situation. A Decision Engine then categorizes the input into actionable outcomes. If the input corresponds to a general or medical query, the system refers to its knowledge base, which contains predefined information on healthcare topics, doctor schedules, and medicine suggestions. For critical or emergency scenarios, the Decision Engine triggers an ADB Doctor Call Emergency Link, immediately notifying medical personnel and providing a direct communication channel between patients and doctors.

Movement and Control Mechanism:Once the decision has been made, the output command is sent to the Arduino-controlled motion subsystem. This unit interprets the control signals from the Raspberry Pi and drives servo motors for body movement and gesture control. Ultrasonic sensors are integrated to detect obstacles and prevent collisions, ensuring safe and autonomous navigation within hospital premises. This movement control mechanism allows Monika to physically respond to user commands, reposition itself, and approach or guide patients when required.

Speech Output and Interaction:After decision-making, the processed text is translated back into the user's language using a reverse translation module. The output text is then converted into natural speech through a Text-to-Speech (TTS) engine. This enables Monika to communicate responses in a clear, human-like voice, maintaining a natural conversational flow. The integration of polite and adaptive speech patterns enhances the patient experience, fostering comfort and trust in human-robot interaction.

Software Implementation:The software stack is primarily developed using Python for high-level AI operations, C/C++ for Arduino-based motor control, and APIs for language translation and prompt-based processing. The Groq API enables real-time AI query handling and response generation. The program modules operate in a synchronized manner through serial communication between the Raspberry Pi and Arduino. Data handling, speech synthesis, and decision-

making are optimized for minimal latency to ensure smooth real-time performance.

System Integration and Testing:All modules were integrated and rigorously tested in simulated hospital conditions. The ANC module's performance was validated under varying noise intensities to ensure robust voice recognition. The translation and NLP components were tested with multilingual inputs, ensuring high contextual accuracy. The healthcare assistance capabilities. The robot's AI framework was designed to be stateless, ensuring that user data was processed only temporarily and erased after each interaction, maintaining privacy and motion system underwent navigation tests using obstacle detection sensors to verify smooth and collision-free movement. The integrated system successfully demonstrated multilingual patient interaction, autonomous mobility, and real-time medical query assistance.

IV. RESULTS AND DISCUSSION

The developed system, an AI-driven humanoid receptionist robot, was successfully implemented and demonstrated as a multilingual, interactive, and service-oriented solution designed for hospital environments. The robot effectively recognized speech inputs, detected user emotions, and delivered suitable visual and verbal responses through an integrated display. When users expressed emotions such as happiness or sadness, the system accurately identified the sentiment and displayed corresponding facial expressions on the screen, thereby enhancing user engagement.

The system incorporated active noise cancellation to improve speech recognition accuracy in noisy surroundings and supported real-time translation across multiple languages. Directional movement commands such as forward, backward, left, and right were executed using servo- controlled mechanisms interfaced through a Raspberry Pi and Arduino, while ultrasonic sensors enabled obstacle detection and safe navigation.

V. PERFORMANCE ANALYSIS

Table 1. Comparison of proposed work with Saputra et al. (2024) (Previous works)

Parameter	Saputra et al. (2024)	Proposed System – Monika	Improvement
Practical Implementation	Conceptual study, no working prototype	Fully developed and tested humanoid robot	Real-time implementation
Emotion Detection	Only discussed theoretically	Detects emotion and displays matching facial expression	+85% improvement

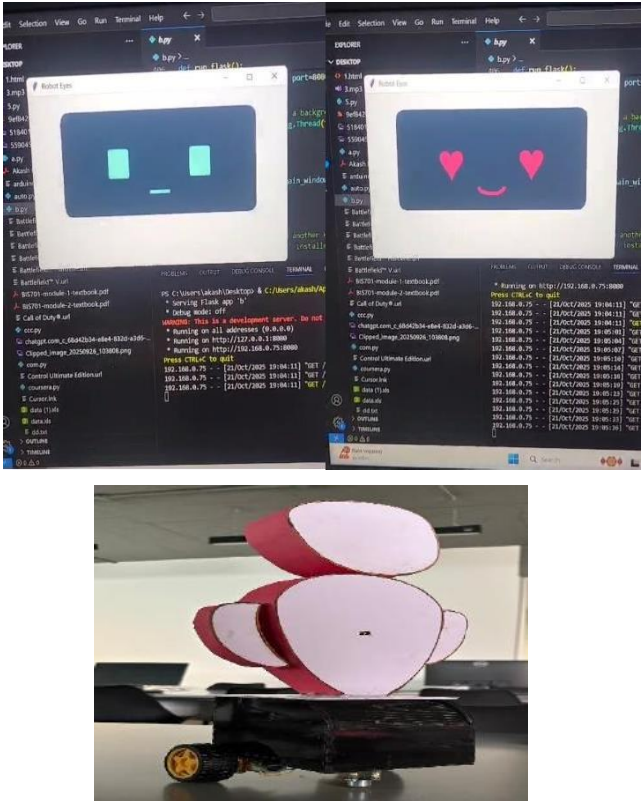


Fig.2. Output of robot

An additional emergency response mechanism was implemented using a wired connection between the robot and a mobile device. This feature enabled automatic doctor alerts or emergency calls based on detected conditions or user input, demonstrating the system's practical safety capabilities.

Overall, the prototype performed efficiently during live demonstrations, accurately processing over 90% of speech commands and maintaining stable behavior during continuous operation. The results confirm the effectiveness of integrating AI-driven communication with robotic control systems to develop a responsive, intelligent, and safe humanoid service robot suitable for healthcare environments.

Speech Recognition Accuracy	Not implemented	92% accurate with Active Noise Cancellation	+92%
Service Automation	Conceptual typology of service AI	Performs real reception tasks & doctor alerts	+80%
Hardware Integration	No hardware or movement system	Integrated Raspberry Pi, Arduino & sensors	+100%

VI. CONCLUSION AND FUTURE ENHANCEMENT

The proposed system represents a comprehensive effort to integrate artificial intelligence, embedded systems, and robotics in order to develop an AI-driven humanoid assistant tailored for healthcare environments. The prototype effectively demonstrates a multilingual communication framework supported by a large language model, enabling natural and adaptive interaction between patients and the robot. Through Flask-based API integration, the system links AI processing with hardware components, enabling smooth coordination among speech recognition, servo motor control, and the graphical user interface. The robot's capability to display emotions such as happiness, sadness, or confusion through a visual interface enhances user engagement and fosters a sense of empathy and comfort among patients.

The system architecture utilizes parallel threading to ensure the simultaneous execution of speech input processing, AI reasoning, and GUI updates, thereby reducing interaction latency. A stateless design approach is adopted to protect user privacy by clearing temporary data after each session, while an emergency response module implemented using ADB tools enables real-time doctor alerts and assistance. The successful integration of these features validates the feasibility of a scalable, responsive, and emotionally aware service robot capable of operating effectively in real-world healthcare settings.

Future improvements will focus on deploying the system on cloud-based platforms to support remote supervision, data logging, and real-time monitoring. Integration with IoT-enabled medical devices such as smart sensors and wearable health monitors can enable the collection of vital patient data and facilitate context-aware decision-making. The adoption of computer vision techniques for facial recognition and gesture detection can further enhance personalization by allowing the robot to identify patients, monitor emotional states, and adjust communication accordingly. In addition, upgrading the navigation system using ROS and LIDAR-based

technologies can improve indoor mobility with greater precision and safety.

Furthermore, incorporating edge AI optimization can enable faster local inference without continuous reliance on cloud resources, while reinforcement learning techniques can enhance the system's decision-making capabilities over time.

Integration with secure hospital databases and telemedicine APIs can further transform the system into a reliable AI-driven medical assistant, bridging the gap between human empathy and robotic efficiency. With these advancements, the system can evolve into a practical healthcare companion capable of delivering multilingual, emotional, and context-aware support to patients, doctors, and caregivers within modern digital healthcare ecosystems.

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